MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

EPM4086 – DIGITAL CONTROL SYSTEMS

(RE)

13 MARCH 2020
9.00a.m – 11.00a.m
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question Paper consists of 5 pages with 4 questions only.
2. Attempt **FOUR** out of **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.
4. Table of Transform pairs has been included in Appendix.

Question 1

(a) (i) Apply block diagram to show analog to digital converter in Digital Control Systems. [4 marks]

(ii) A machine gun mounted on a ship can be modeled by the mass-spring-friction combination as shown in **Figure Q1**. The force acting on the mass is in the form of impulses with strength $F(t)$ at time intervals of $t = nT$, $n = 0, 1, 2, \ldots..$

Assume that at $t = 0$, m is the mass of gun at rest in its equilibrium position of $x(0) = 0$. Write an equation of motion for the system and solve for displacement $x(t)$ of m for $t > 0$. Let k be the linear spring constant and equals to $m(u^2 + \omega_s^2)$, where u = constant, $\omega_s = 2\pi/T$, and f = viscous friction coefficient = $2mu$. [9 marks]

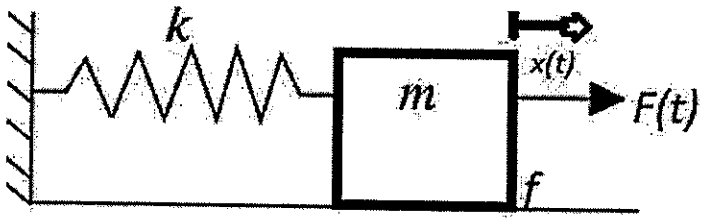

Figure Q1: Mass-spring-friction system

(b) Find the inverse Z-transform g(k) for G(z) given by the expression.

$$G(z) = \frac{3z}{(z-2)(z-6)}$$

(i) Use partial-fraction expansion [6 marks]

(ii) Use long division [6 marks]

Continued ...

Question 2

(a) For the sampled-data system shown in **Figure Q2a**, determine the output $y(k)$ when $r(kT)$ is unit step ($T = 1$ second) and $D(z) = \frac{1}{s}$.

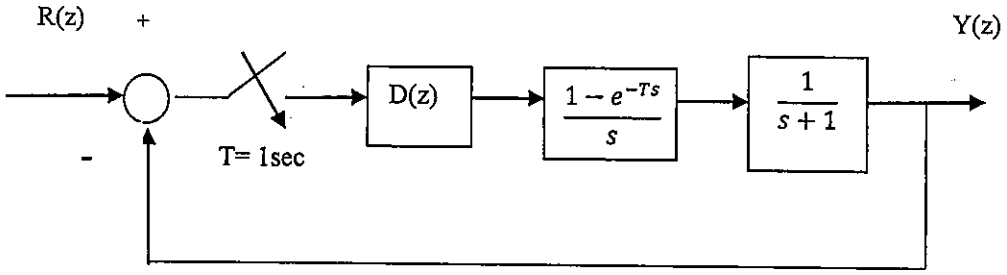

Figure Q2a

[13 marks]

(b) Determine the discrete transfer function $Y(z)/U(z)$ for the following state space representation.

$$x(k+1) = Ax(k) + Bu(k)$$
$$y(k) = Cx(k) + Du(k)$$

where $A = \begin{bmatrix} 0 & 1 \\ -0.5 & 2.4 \end{bmatrix}$, $B = \begin{bmatrix} 0.5 \\ 1 \end{bmatrix}$, $C = [2 \quad 0]$, $D = 0$

The state variable is $x(k) = \begin{bmatrix} y(k) \\ y(k+1) - 1.5u(k) \end{bmatrix}$

[12 marks]

Continued ...

Question 3

(a) What are the three main Nyquist criterions for Digital Control Systems? [9 marks]

(b) Consider the following discrete characteristic equation

$$F(z) = z^3 + 2az^2 + az - 0.4$$

(i) Find the value of a such that $F(z)$ satisfies the three preliminary Jury Test. [5 marks]

(ii) What is the condition of stability [7 marks]

(iii) Determine the range of a to ensure the system to be stable. [4 marks]

Question 4

(a) A case of special interest occurs when a state feedback control law is chosen. Describe what is the deadbeat control law? [8 marks]

(b) For the discrete-time system modeled by the following dynamic equations.

$X(k+1) = AX(k) + BU(k)$
$Y(k) = CX(k)$

where $A = \begin{bmatrix} 1 & 1 \\ 0.5 & 4 \end{bmatrix}, B = \begin{bmatrix} 1 \\ -1 \end{bmatrix}, C = [1 \quad 1]$

(i) Determine the transfer function $Y(z)/U(z)$. [7 marks]

(ii) Design the state diagram of the system. [10 marks]

Continued ...

APPENDIX

TABLE OF TRANSFORM PAIRS

Time function $f(t); t>0$	Laplace Transform $F(s)$	Z-transform $F(z)$, T = Sampling time
$u_s(t)$	$1/s$	$z/(z-1)$
t	$1/s^2$	$Tz/(z-1)^2$
t^2	$2/s^3$	$T^2 z(z+1)/(z-1)^3$
ε^{-at}	$1/(s+a)$	$z/(z-\varepsilon^{-aT})$
$1-\varepsilon^{-at}$	$a/\{s(s+a)\}$	$z(1-\varepsilon^{-aT})/\{(z-1)(z-\varepsilon^{-aT})\}$
$t\varepsilon^{-at}$	$1/(s+a)^2$	$Tz\varepsilon^{-aT}/(z-\varepsilon^{-aT})^2$
$\sin at$	$a/(s^2+a^2)$	$z\sin aT/(z^2-2z\cos aT+1)$
$\cos at$	$s/(s^2+a^2)$	$z(z-\cos aT)/(z^2-2z\cos aT+1)$
$\varepsilon^{-at}\sin bt$	$b/\{(s+a)^2+b^2\}$	$z\varepsilon^{-aT}\sin bT/(z^2-2z\varepsilon^{-aT}\cos bT+\varepsilon^{-2aT})$
$\varepsilon^{-at}\cos bt$	$(s+a)/\{(s+a)^2+b^2\}$	$(z^2-z\varepsilon^{-aT}\cos bT)/(z^2-2z\varepsilon^{-aT}\cos bT+\varepsilon^{-2aT})$

End of Paper